



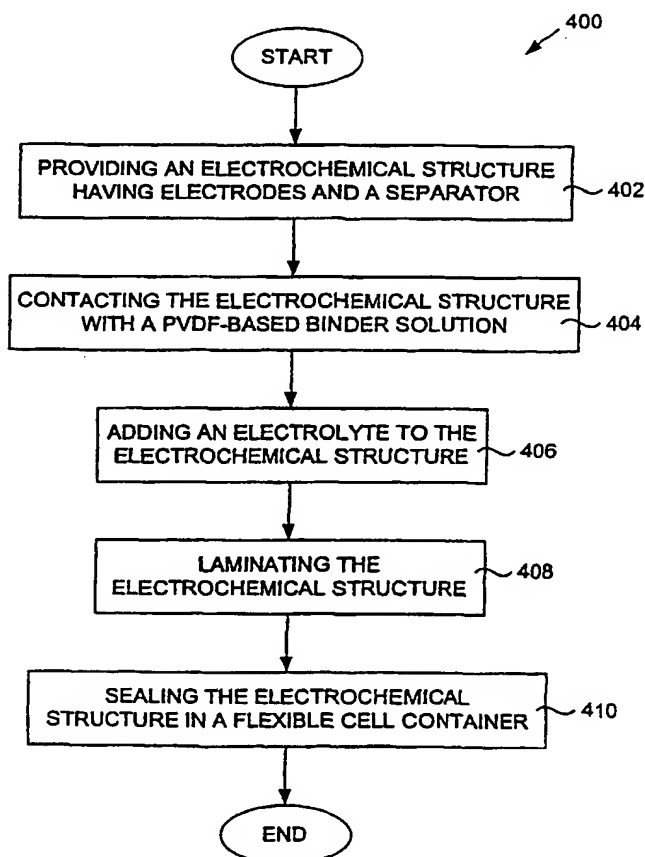
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: METHOD OF FABRICATING A LAMITATED BATTERY CELL

## (57) Abstract

Provided are alternative fabrication methods for a lithium-ion secondary battery cell (300). Briefly, the present invention provides processes wherein a binder (105) is applied to a battery separator (104) after winding or stacking the electrodes (106, 108). This is accomplished by soaking previously wound or stacked electrochemical structures, including positive (106) and negative (108) electrodes and a porous separator (104), in a solution containing a binder (105).



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## METHOD OF FABRICATING A LAMITATED BATTERY CELL

BACKGROUND OF THE INVENTION

The present invention relates to electrochemical cells and methods for their  
5 manufacture. More particularly, the invention relates a method of fabricating lithium-  
ion secondary battery cells.

Lithium-ion secondary battery cells are primarily composed of a positive  
electrode, a negative electrode, and an ion conducting separator interposed between  
the two electrodes. Conventional lithium-ion battery cells have typically used as a  
10 separator a porous polymer film, such as polyethylene, polypropylene,  
polytetrafluoroethylene, polystyrene, polyethyleneterphtalate, ethylenepropylene  
diene monomer (EPDM), nylon and combinations thereof, filled with an electrolyte  
solution. Also, conventional cells are enclosed in a rigid case, typically made of  
stainless steel, in order to apply pressure to the cell components to maintain good  
15 electrical connections between the components.

In order to reduce the size and weight of battery cells, more recently attempts  
have been made to develop lithium-ion battery cells which do not require the rigid  
case in order to maintain good electrical connections between the battery cell's  
components. Various adhesives and binders have been proposed in order to provide  
20 sufficient adhesive strength between the cell components. Such binders include, for  
example, polyurethane, polyethylene oxide, polyacrylonitrile, polymethylacrylate,  
polyacrylamide, polyvinylacetate, polyvinylpyrrolidone, polytetrafluoroethylene,

glycol diacrylate, polyvinylidene fluoride (PVDF), and copolymers of the foregoing and combinations thereof.

Previously described methods for fabricating lithium-ion battery cells have involved applying a binder resin solution to a separator and, before the resin dried, 5 adhering and laminating the positive and negative electrodes to the separator. Thereafter, the binder resin solvent was evaporated to form the battery cell electrode laminate. Subsequently, the laminate was impregnated with electrolyte solution in a pouch, which was then sealed to complete the cell.

Thus, the conventional battery cell manufacturing processes use coating, 10 casting or spray-coating techniques for applying binder resin on separate elements (separator and/or electrodes) prior to winding or stacking. One drawback of these conventional processes is that the separator is softened and rendered susceptible to wrinkling tearing or other damage by the coating of binder prior to winding or stacking and is sometimes damaged during the assembly procedures. In addition, in 15 order to improve manufacturing efficiency and economy, ways of reducing the number of process steps or amount of materials used are constantly sought. Thus, an improved process of fabricating a lithium-ion battery that improved quality while reducing cost would be desirable.

### SUMMARY OF THE INVENTION

To achieve the foregoing, the present invention provides alternative fabrication methods for a lithium-ion secondary battery cell. Briefly, the present invention provides a process wherein a binder is applied to a battery separator after  
5 winding or stacking the electrodes. This is accomplished by soaking previously wound or stacked electrochemical structures, including positive and negative electrodes and a separator, in a solution containing a suitable binder.

The process of the present invention has the advantage that conventional steps used for a standard lithium-ion battery manufacture can still be used until soaking,  
10 with the advantage that the steps of coating the electrodes and separator with a binder prior and/or during to assembly are no longer necessary. Only one extra drying step is needed after that, and the final battery assembly is similar to standard lithium-ion batteries. Moreover, by assembling (winding or stacking) the cell's electrode components prior to introducing the binder, no damage to the separator is risked in the  
15 assembly procedure (winding or stacking), as is the case with pre-coated separators in accordance with the conventional processes.

In one aspect, the invention provides a method of making a battery cell. The method include providing an electrochemical structure having a positive electrode, a negative electrode, and a separator separating the two electrodes. The electrochemical  
20 structure is then contacted with a binder solution, whereby the separator is coated by the binder solution. An electrolyte is added and the electrochemical structure is laminated and sealed in a flexible cell container.

In another aspect, the invention provides a method of rigidifying an electrochemical structure. The method involves providing an electrochemical cell structure having a positive electrode, a negative electrode, and a separator separating the two electrodes. The electrochemical structure is then contacted with a binder  
5 solution so that the separator is coated by the binder solution.

These and other features and advantages of the present invention are described below with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 depicts a portion of a single laminate layer of an electrochemical structure in accordance with one embodiment of the present invention.

Figs. 2A and 2B illustrate basic jellyroll and stacked electrochemical  
5 structures for cells in accordance with the present invention.

Fig. 3 depicts a completed battery cell in accordance with the present invention.

Fig. 4 depicts a flow chart presenting aspects the fabrication of a battery cell in accordance with one embodiment of the present invention.

10 Figs. 5 and 6 depict graphical data from experiments conducted to test performance characteristics of battery cells fabricated in accordance with preferred embodiments of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference will now be made in detail to preferred embodiments of the invention. Examples of the preferred embodiments are illustrated in the accompanying drawings. While the invention will be described in conjunction with  
5 these preferred embodiments, it will be understood that it is not intended to limit the invention to such preferred embodiments. On the contrary, it is intended to cover alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims. In the following description, numerous specific details are set forth in order to provide a thorough  
10 understanding of the present invention. The present invention may be practiced without some or all of these specific details. In other instances, well known process operations have not been described in detail in order not to unnecessarily obscure the present invention.

The present invention provides alternative fabrication methods for a lithium-  
15 ion secondary battery cell. Briefly, the present invention provides a process wherein a binder is applied to a battery separator after winding or stacking the electrodes. This is accomplished by soaking previously wound or stacked electrochemical structures, including positive and negative electrodes and a separator, in a solution containing a suitable binder.

20 The process of the present invention has the advantage that conventional steps used for a standard lithium-ion battery manufacture can still be used until soaking, with the omission of the steps of coating the electrodes and separator with a binder. Only one soaking and one drying step are needed after that, and the final battery

assembly is similar to standard lithium-ion batteries. Moreover, by assembling (winding or stacking) the cell's electrodes and separator components ("electrochemical structure") prior to introducing the binder, no damage to the separator is risked in the assembly procedure, as is the case with pre-coated separators  
5 while winding or stacking in accordance with the conventional processes.

Referring to Fig. 1, a portion 100 of a single laminate layer 102 of an electrochemical structure in accordance with one embodiment of the present invention is illustrated. As further described below, the electrochemical structure is typically in the form of jellyroll (wound laminate) or stack. The layer 102 includes a porous  
10 separator 104 interposed between a positive electrode 106 and a negative electrode 108. The separator is impregnated (including being coated) with a binder 105 to enhance the bonding of each of the structure's components to each other. The electrodes 106, 108 are typically formed on current collectors 110, 112, respectively, which may be composed of a highly conductive metal, such as copper or aluminum.  
15 For example, the positive electrode 106 may be composed of a cathode material 114 on an aluminum foil current collector 110, and the negative electrode 108 may be composed of an anode material 116 on a copper foil current collector 112. In a preferred embodiment, the separator 104 is porous.

In one embodiment of this aspect of the present invention, the components of  
20 the electrochemical structure may be composed of appropriate materials known to those of skill in the art. Suitable materials for a lithium-ion cell include, for example, for the positive electrode, carbon (as an electronic conductor), active material (e.g., lithium cobalt oxide, lithium manganese oxide, or lithium nickel oxide), and a binder

(such as PVDF), and for the negative electrode, carbon as an active material with a binder (such as PVDF). As noted above, the electrodes are typically formed on current collectors, which may be composed of a highly conductive metal, such as copper or aluminum. The separator may be composed of a porous polyolefin, preferably polyethylene, polypropylene, or a combination of the two, coated as described below. Other possible separator materials include polytetrafluoroethylene, polystyrene, polyethyleneterephthalate, ethylenepropylene diene monomer (EPDM), nylon and combinations thereof. The separator is typically filled with a liquid electrolyte composed of a solvent and a lithium salt. Sample liquid electrolyte compositions for lithium ion cells in accordance with the present invention may include solvents such as propylene carbonate, ethylene carbonate, diethyl carbonate, dimethyl carbonate, dipropyl carbonate, dimethyl sulfoxide, acetonitrile and combinations thereof, a lithium salt having  $\text{Li}^+$  as the cation and one of  $\text{PF}_6^-$ ,  $\text{AsF}_6^-$ ,  $\text{BF}_4^-$ ,  $\text{ClO}_4^-$ ,  $\text{CF}_3\text{SO}_3^-$ ,  $\text{N}(\text{CF}_3\text{SO}_2)_2^-$  as the anion.

As noted above, an electrochemical structure in accordance with the present invention is typically in the form of a "jellyroll" (wound laminate) or stack. Figs. 2A and 2B illustrate basic jellyroll and stacked electrochemical structures for cells in accordance with the present invention. Fig. 2A depicts an enlarged cross-sectional view of a cell (along the line A-A, Fig. 3) depicting a jellyroll structure 200 in accordance with one embodiment of the present invention. The jellyroll design 200 is formed by winding a laminate layer 202. Fig. 2B depicts an enlarged cross-sectional view of a cell (along the line A-A, Fig. 3) depicting a stacked structure 210 in accordance with one embodiment of the present invention. The stack 210 may be formed by stacking a series of laminate layers 212. In each case, a positive lead 204

is attached, e.g., by welding, to a portion of the positive electrode's current collector and a negative lead 206 is attached to a portion of the negative electrode's current collector. Winding, stacking, and associated fabrication techniques for cells described herein are well known to those skill in the art.

5 Referring to Fig. 3, in a completed battery cell 300, the electrochemical structure is packaged in a cell container 302. In one embodiment of the present invention, the cell container may be composed of a substantially gas-impermeable barrier material composed a polymer-laminated metal material that is lightweight and flexible. Such cell container materials are well known in the art for use in packaging  
10 gel-polymer as well as solid state polymer cell batteries. A particularly preferred cell container material is polymer-laminated aluminum foil, such as product number 96031, available from Pharma Center Shelbyville, Inc, of Shelbyville, KY. Leads 304, 306 connected to each of the positive and negative electrodes of the cell as described above, extend from the sealed cell container 302 for external electrical  
15 connection.

The present invention is primarily directed to a process for applying a binder material to an electrochemical structure (in particular, the separator) to provide the final battery cell with some rigidity after lamination/curing. In accordance with the present invention a "jellyroll" or stack electrochemical structure may be dip-coated or  
20 otherwise soaked in a binder solution under pressure, e.g., in a pressurized vessel. The binder solution may include polyurethane, polyethylene oxide, polyacrylonitrile, polymethylacrylate, polyacrylamide, polyvinylacetate, polyvinylpyrrolidone, polytetrafluoroethylene, glycol diacrylate, polyvinylidene fluoride (PVDF), and

copolymers of the foregoing and combinations thereof. In a preferred embodiment, the binder solution may be a PVDF homopolymer, or it may also include a PVDF copolymer, for example with hexafluoropropylene (HFP) (e.g., about 0-8%, for example 5%) or chlorotrifluoroethylene (CTFE), for example.

5 In general, the binder is dissolved in a solvent; from about 1% to 30% binder in solvent, preferably about 6% binder in solvent. Suitable solvents will preferably be those in which the binder is highly soluble. Particularly preferred are solvents which also have relatively low boiling points. Suitable solvents include: acetone, tetrahydrofuran, methyl ethyl ketone, dimethyl formamide, dimethyl acetamide,  
10 tetramethyl urea, dimethyl sulfoxide, trimethyl phosphate, N-methyl pyrrolidone (NMP). These solvents are particularly useful for PVDF-based binder solutions.

One example of a suitable binder solution is PVDF-acetone-NMP. The binder solution may be about 1 to 20% by weight PVDF in solvent (e.g., 80% acetone/20% NMP). The soaking of the separator with the binder solution takes place after the  
15 formation of the electrochemical structure, but may take place either before or after the structure is placed in a cell container.

For example, in accordance with one embodiment of the present invention, a jellyroll is wound or a stack of electrodes prepared using a standard separator and techniques. A 12% (by weight) PVDF solution in acetone is prepared. The jellyroll  
20 or stack is placed into a cell container in the form of a pouch (e.g., sealed on three sides) with one side open for "wetting" purposes. The desired quantity of PVDF-based binder solution is placed into the pouch. Under pressure (e.g., about 100 psi), the separator is impregnated with PVDF solution, and then dried, e.g., under vacuum,

to remove the low boiling point acetone solvent. The cell is then wetted with electrolyte under pressure and sealed. The PVDF impregnation, drying and electrolyte wetting can take place in the same vessel.

In accordance with one embodiment of the present invention, binder solutions  
5 are formulated with a low boiling/high solubility ("good") solvent and a higher boiling/nor or low solubility ("bad") solvent to dissolve the binder and coat it on the separator by the soaking method of the present invention. When the separator in the electrochemical structure is subsequently dried by evaporation, the lower boiling solvent is removed first. The binder precipitates from solution. Thus, the coating of  
10 binder solution on the separator is composed of connected pockets of the bad solvent. The bad solvent is removed upon further drying leaving a porous coating of binder on the separator.

In accordance with this embodiment of the invention, combinations of "good" and "bad" solvents may also include intermediate (i.e., moderate solubility for the  
15 binder material) or latent i.e., poor solubility for the binder material). For example, for a PVDF-based binder solution in accordance with one embodiment of the present invention, good solvents may include: acetone, tetrahydrofuran, methyl ethyl ketone, dimethyl formamide, dimethyl acetamide, tetramethyl urea, dimethyl sulfoxide, trimethyl phosphate, N-methyl pyrrolidone. Intermediate solvents include:  
20 butyrolactone, isophorone, carbitol acetate. Latent solvents include: methyl isobutyl ketone, n-butyl acetate, cyclohexanone, diacetone alcohol, diisobutyl ketone, ethyl aceto acetate, triethyl phosphate, propylene carbonate, ethylene carbonate, dimethyl carbonate, diethyl carbonate, dimethyl phthalate, glycol ethers, glycol ether esters;

carbonates generally. And bad solvents include: pentane, methyl alcohol, hexane, carbon tetrachloride, benzene, trichloroethylene, isopropyl acetate, ethyl alcohol, toluene, tetrachloroethylene, xylene, o-chlorobenzene, decane. Generally, aliphatic hydrocarbons, aromatic hydrocarbons, chlorinated solvents, and alcohols. In a  
5 preferred embodiment, the ratio of solvents can be from about 99% good/1% bad (including intermediate and/or latent) to about 50% good/50% bad, preferably about 80% good/20% bad.

For example, an electrochemical structure containing a microporous polyethylene film may be coated with a solution of PVDF dissolved in a mixture of 2-  
10 butanone and diethyl carbonate. 2-butanone is a good solvent for PVDF and has a boiling point of 80°C. Diethyl carbonate is a bad solvent for PVDF and has a boiling point of 127°C. When the electrochemical structure is dried the separator is coated with a porous PVDF binder layer.

Lamination of the electrodes and separator may be conducted according to any  
15 suitable method such as are known in the art, and may take place either before or after the binder solution is dried according to alternative embodiments of the present invention. Moreover, lamination may take place before or after the cell is sealed. Lamination and sealing techniques for cells such as those described herein are well known to those skill in the art, and may use, for example a lamination/curing step  
20 involving any suitable energy source, such as U.V., I.R., R.F. ultrasound, heat, etc.

An alternative embodiment of the present invention provides for using a solution of a binder dissolved in a low boiling point solvent in order to deposit binder onto the separator and soak the separator with electrolyte at the same time. In a

preferred embodiment of this aspect of the present invention, a jellyroll or stack may be placed in a cell container pouch with a binder/low boiling point solvent/electrolyte solution (e.g., 1% to 30% binder, 10% to 90% electrolyte, 10% to 90% of solvent) (for example, PVDF-acetone-electrolyte (e.g.,  $\text{LiPF}_6$  in 50% DEC/50% EC)) under  
5 pressure in a pressurized vessel. The so-soaked jellyroll or stack is dried in order to remove the low boiling point solvent, e.g., under vacuum using the appropriate parameters as are well known in the art. The PVDF then remains on the separator and the electrolyte remains in the jellyroll or stack. The pouch may then be sealed.

For example, in accordance with one embodiment of the present invention, a  
10 jellyroll is wound or a stack of electrodes prepared using a standard separator and techniques. A 12% (by weight) PVDF solution in acetone is prepared. The jellyroll or stack is placed into a pouch leaving one side open for "wetting" purposes. The desired quantity of PVDF/solvent/electrolyte solution, for example, a 10% solvent binder solution-90% electrolyte solution in which the binder solution is composed of  
15 6% PVDF in acetone and the electrolyte is  $\text{LiPF}_6$  in 50%EC/50%DEC, is placed into the pouch. Under pressure, the separator is impregnated with PVDF/electrolyte solution followed by vacuum to remove the acetone. The addition of PVDF and electrolyte wetting take place simultaneously.

Fig.4 illustrates a process flow 400 for soaking an electrochemical structure  
20 and fabricating a battery cell in accordance with one embodiment of the present invention. Processes in accordance with the present invention may include up to several additional steps not described or illustrated here in order not to obscure the present invention. In addition, some steps of the process may be omitted according to

some embodiments of the present invention, for example, where an electrochemical structure is soaked in a PVDF-based binder solution but not (at least immediately) fabricated into a battery cell. Also, the order of the steps is not limited to that presented in Fig.4; certain steps may be reversed in order or combined, for example as

5 described elsewhere herein.

The process flow 400 begins by providing an electrochemical structure having electrodes and a separator as described above (402). The structure is contacted with a binder solution in accordance with the present invention (404). The binder solution may have a variety of compositions, as described herein, and the contact may take

10 place without or inside a cell container. An electrolyte is added to the structure (406), and the structure is laminated/cured (408) and sealed in a flexible cell container (410). As noted above, in at least one embodiment of the present invention, the electrolyte may be combined with the binder solution and added to the electrochemical structure in a single step. Also as described herein, solvents having particular properties (e.g.,

15 good/bad solvent combinations) may be used in conjunction with the binder and one or more drying steps (e.g., under vacuum) typically take place to remove volatile solvents following addition of the binder.

### EXAMPLES

The following examples provide additional experimental details relating to

20 processes in accordance with the present invention in order to show the successful lamination/curing and electrochemical performance of so-prepared lithium-ion batteries. This material intended to assist in an understanding of the present invention and should not be construed to limit the scope of the invention.

Example 1: Impregnation of Separator by PVDF Soaking

Three prismatic jellyrolls were weighed. One control was kept in a dry-box. Two were soaked in an 11 weight percent solution of PVDF in 1-methyl-2-pyrrolidinone/acetone (50/50 w/w) for 45 minutes at 100 Psi, dried *in vacuo* at 60°C  
5 for 2 hours and reweighed. Two platens were placed in an oven at 90°C for a few hours. The three jellyrolls were placed in a oven at 90°C for 30 minutes. The rolls were gently hand-pressed in between the two hot platens at 90°C for 1 minute followed by cold pressing in between two cold platens at 250 Psi for 1 minute.

One of the soaked jellyrolls was taken apart to check the quality of the  
10 adhesion in the jellyroll while the other two were dried again. The two remaining rolls were wetted with electrolyte and sealed in an aluminum/polymer laminate inside the dry-box, removed from the dry-box and placed in an oven at 90°C for 10 minutes. The two sealed cells were then charged to 4.2 V, discharged to 3.0 V, vented and resealed.

15 The rolls which were soaked in the PVDF solution increased in weight by 4 % and thickness by 8-9 % indicating that PVDF was incorporated into the jelly wrap.

An examination of one of the PVDF-dipped rolls showed that the electrodes were bonded to the separator almost all along the electrode length. The center of the roll and the sides of the electrodes were the most difficult spots to take apart due to a  
20 better impregnation of the separator by PVDF.

The first charge/discharge of the two sealed cells is shown in Fig. 5. 703 is the control and 701 is the roll soaked in PVDF solution. The capacity of the two cells is similar.

Accordingly, it is concluded that soaking jellyrolls in PVDF solutions is an effective way to achieve lamination/curing within a jellyroll without substantially affecting performance.

Example 2: Impact of Soaking Jellyrolls in a PVDF Solution on Capacity and Rate Capability

Two cells were built to measure the impact of soaking jellyrolls in a PVDF solution on capacity and rate capability. Two jellyrolls were dried *in vacuo* at 90°C for a few days inside a dry-box. The jellyrolls were then soaked in a 6 weight percent solution of PVDF in acetone/1-methyl-2-pyrrolidinone (50/50 w/w) at 100 psi pressure for 45 m. and dried *in vacuo* at 90°C for 48 hours and reweighed. The cells were wetted with electrolyte, sealed in an aluminum/polymer laminate, heated at 90°C for 30 m. and immediately pressed to a thickness of 6.8 mm.

The cells were formed, vented, resealed and tested for rate capability. This involves discharging cells at 4C, 3C, 2C, 1C, C/2, C/5 and C/10 (where 1C rate is defined as the current necessary to fully discharge the battery in one hour, as is well known in the art) rates with a full charge in between every discharge. A control cell was also tested for rate capability.

Jellyrolls soaked in the PVDF solution increased in weight by 1.3 % indicating that PVDF was incorporated. The rate capability of the soaked and control cells is

similar. Fig. 6 shows the capacity versus rate for a control and one of the soaked cells. At a rate of 2C, 88% of the capacity obtained at C/10 is retained by both cells.

Accordingly, it is concluded that cell performance, specifically capacity and rate capability, are unaffected by additional PVDF added to the cell via solution.

5        Conclusion

The processes of the present invention provide the benefit of avoiding damage to the separator during winding or stacking procedures, and also offer decreased material cost since it is likely that less binder is required in the inventive soaking protocol than in conventional coating of electrodes and separator prior to or during  
10 assembly. In addition, the inventive technique does not result in any deterioration in performance of battery cells so formed.

Although the foregoing invention has been described in some detail for purposes of clarity of understanding, it will be apparent that certain changes and modifications may be practiced within the scope of the appended claims. It should be  
15 noted that there are many alternative ways of implementing both the process and apparatuses of the present invention. Accordingly, the present embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein.

*What is claimed is*

### CLAIMS

1. A method of making a battery cell, comprising:  
providing an electrochemical structure having,  
5 a positive electrode,  
a negative electrode, and  
a separator separating the two electrodes; and  
contacting the electrochemical structure with a binder solution, whereby the  
separator is coated by the binder solution;  
10 adding an electrolyte to the electrochemical structure;  
laminating the electrochemical structure; and  
sealing the electrochemical structure in a flexible cell container.
2. The method of claim 1, wherein the electrochemical structure is placed in a  
pouch formed by the partially-sealed flexible cell container prior to being contacted  
15 with the binder solution.
3. The method of claim 1, wherein the electrochemical structure is placed in a  
pouch formed by the partially-sealed flexible cell container after being contacted with  
the binder solution.
4. The method of claim 1, wherein the electrochemical structure is laminated  
20 prior to being contacted with the binder solution.
5. The method of claim 1, wherein the electrochemical structure is laminated  
after being contacted with the binder solution.
6. The method of claim 1, wherein the binder solution is one of a solution of  
polyvinylidene fluoride (PVDF), polyurethane, polyethylene oxide, polyacrylonitrile,  
25 polymethylacrylate, polyacrylamide, polyvinylacetate, polyvinylpyrrolidone,  
polytetrafluoroethylene, glycol diacrylate, and copolymers of the foregoing and  
combinations thereof in a solvent.

7. The method of claim 6, wherein said solvent is one of acetone, tetrahydrofuran, methyl ethyl ketone, dimethyl formamide, dimethyl acetamide, tetramethyl urea, dimethyl sulfoxide, trimethyl phosphate, n-methyl pyrrolidone and intermediate solvents.
- 5 8. The method of claim 7, wherein said solution further comprises a second solvent.
9. The method of claim 8, wherein said second solvent is one of n-methyl pyrrolidone, butyrolactone, isophorone, carbitol acetate, methyl isobutyl ketone, n-butyl acetate, cyclohexanone, diacetone alcohol, diisobutyl ketone, ethyl acetate, triethyl phosphate, propylene carbonate, ethylene carbonate, dimethyl carbonate, diethyl carbonate, dimethyl phtalate, glycol ethers, glycol ether esters, pentane, methyl alcohol, hexane, carbon tetrachloride, benzene, trichloroethylene, isopropyl acetate, ethyl alcohol, toluene, tetrachloroethylene, xylene, o-chlorobenzene, and decane.
- 10 10. The method of claim 1, wherein said binder solution is about 1 to 30% binder in solvent.
11. The method of claim 10, wherein said the binder solution is about 12% (by weight) PVDF in acetone.
12. The method of claim 1, wherein the electrochemical structure is one of a jellyroll and a stack.
- 20 13. The method of claim 1, wherein the electrolyte is mixed with the binder solution and both the electrolyte and the binder are contacted with the electrochemical structure in a single step.
14. The method of claim 13, wherein the binder-electrolyte mixture is about 20 to 99% electrolyte.
- 25 15. The method of claim 14, wherein the binder-electrolyte mixture is about 90% electrolyte, 10% PVDF solution in solvent.
16. The method of claim 1, further comprising drying the electrochemical structure after contacting with the binder solution to remove solvent in the binder solution prior to sealing the cell.
- 30 17. The method of claim 16, wherein the drying is facilitated by application of a vacuum.

18. The method of claim 1, wherein the separator is porous.
19. The method of claim 18, wherein the separator is impregnated with the binder solution under pressure.
20. The method of claim 18, wherein the binder solution comprises at least two solvents, wherein a first of said at least two solvents has higher solubility for the binder than a second of said at least two solvents, and further comprising evaporating said at least two solvents such that a porous coating of binder is formed on the separator.
21. The method of claim 1, wherein said battery cell is a lithium-ion battery cell.
22. The method of claim 1, wherein the flexible cell container comprises polymer laminated aluminum.
23. A method of rigidifying an electrochemical structure, comprising:  
providing an electrochemical cell structure having,  
a positive electrode,  
a negative electrode, and  
a separator separating the two electrodes; and  
contacting the electrochemical structure with a binder solution;  
whereby the separator is coated by the binder solution.
24. The method of claim 23, wherein the binder solution is one of a solution of polyvinylidene fluoride (PVDF), polyurethane, polyethylene oxide, polyacrylonitrile, polymethylacrylate, polyacrylamide, polyvinylacetate, polyvinylpyrrolidone, polytetrafluoroethylene, glycol diacrylate, and copolymers of the foregoing and combinations thereof in a solvent.
25. The method of claim 23, further comprising drying the electrochemical cell structure after contacting with the binder solution to remove solvent in the binder solution.
26. The method of claim 23, wherein the separator is porous.

27. The method of claim 26, wherein the separator is impregnated with the binder solution under pressure.
28. The method of claim 26, wherein the binder solution comprises at least two solvents, wherein a first of said at least two solvents has higher solubility for the binder than a second of said at least two solvents, and further comprising evaporating said at least two solvents such that a porous coating of binder is formed on the separator.
29. The method of claim 28, wherein the binder solution comprises between about 99% of the lower solubility solvent/1% of the higher boiling solvent and 50% of the lower solubility solvent/50% of the higher boiling solvent.
30. The method of claim 29, wherein the binder solution comprises about 80% of the lower solubility solvent/20% of the higher boiling solvent.

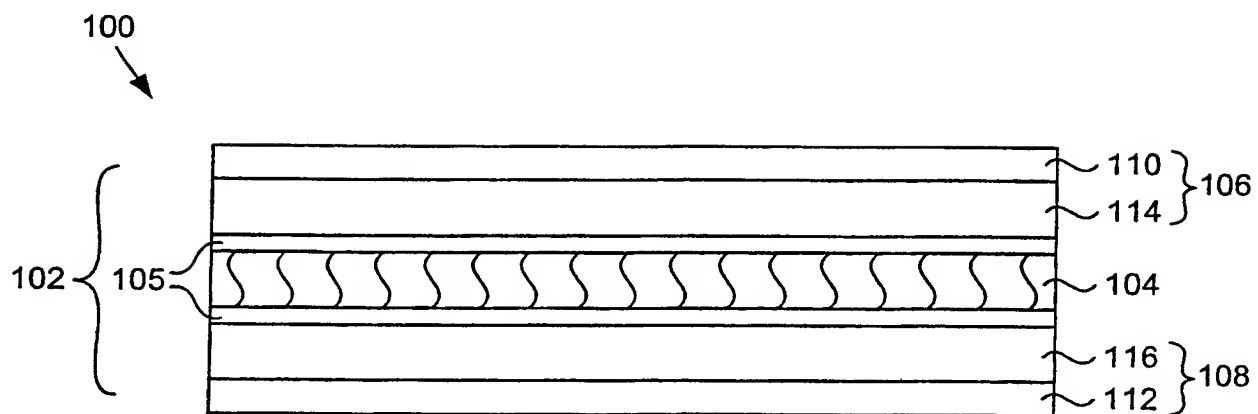


FIG. 1

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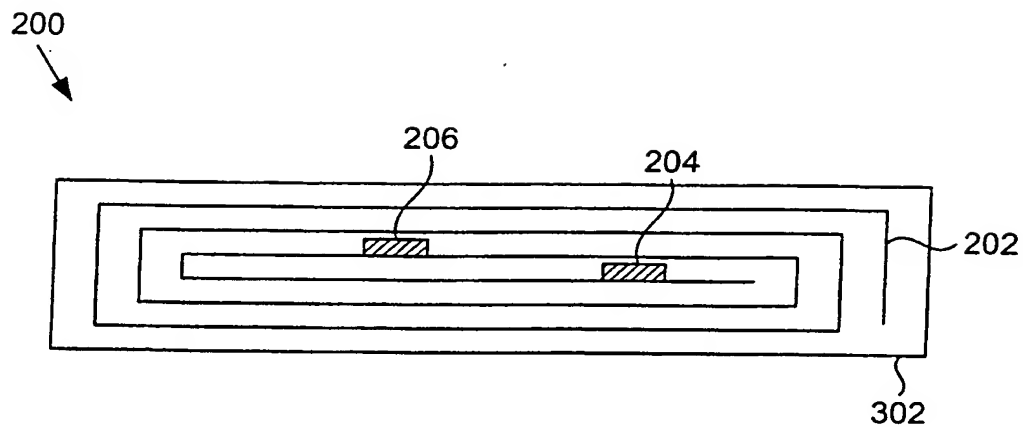


FIG. 2A

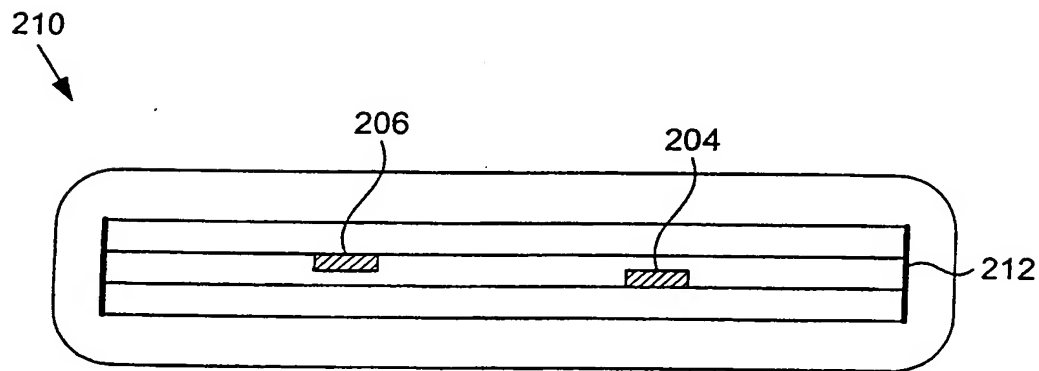


FIG. 2B

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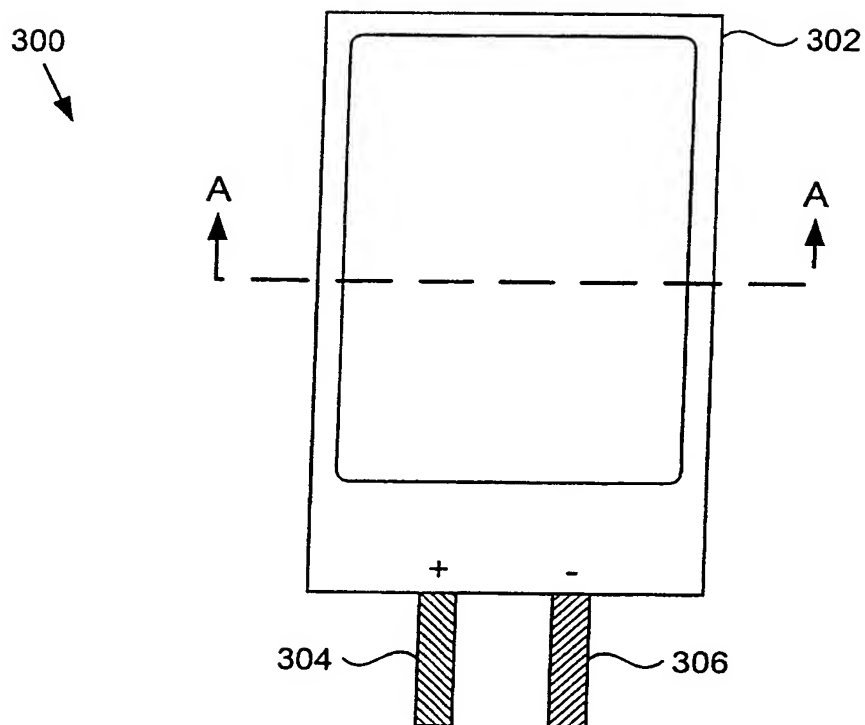


FIG. 3

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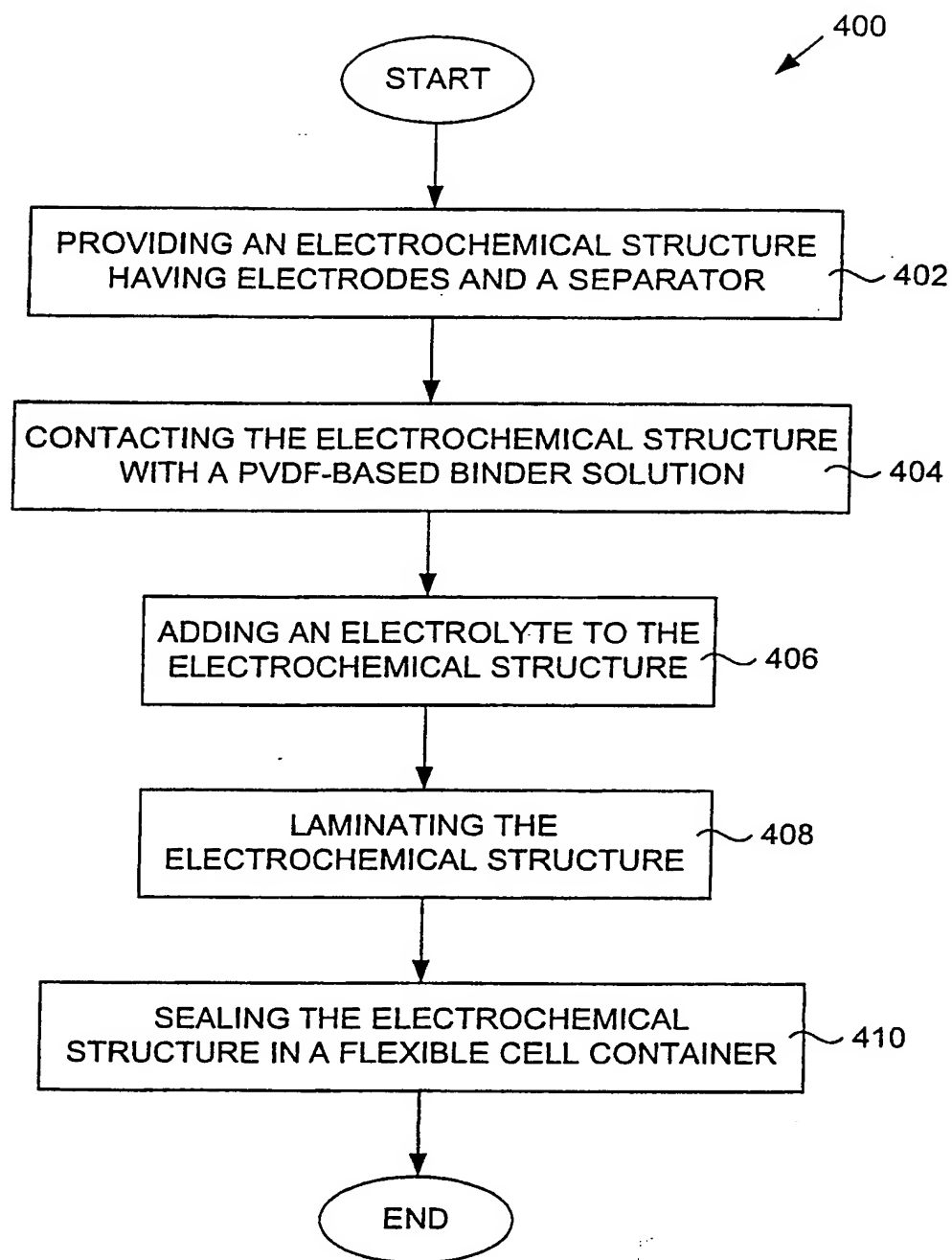


FIG. 4

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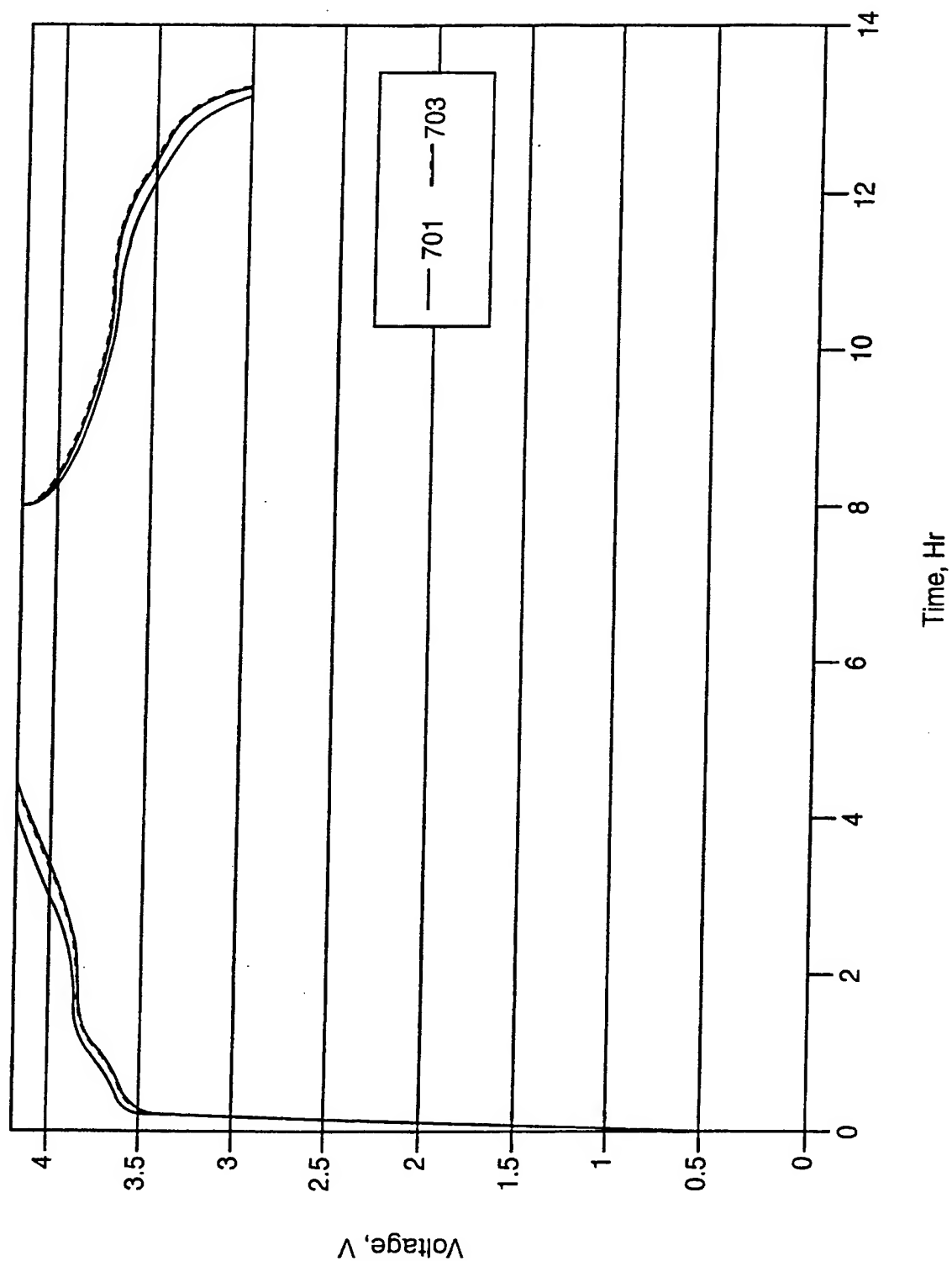


FIG. 5

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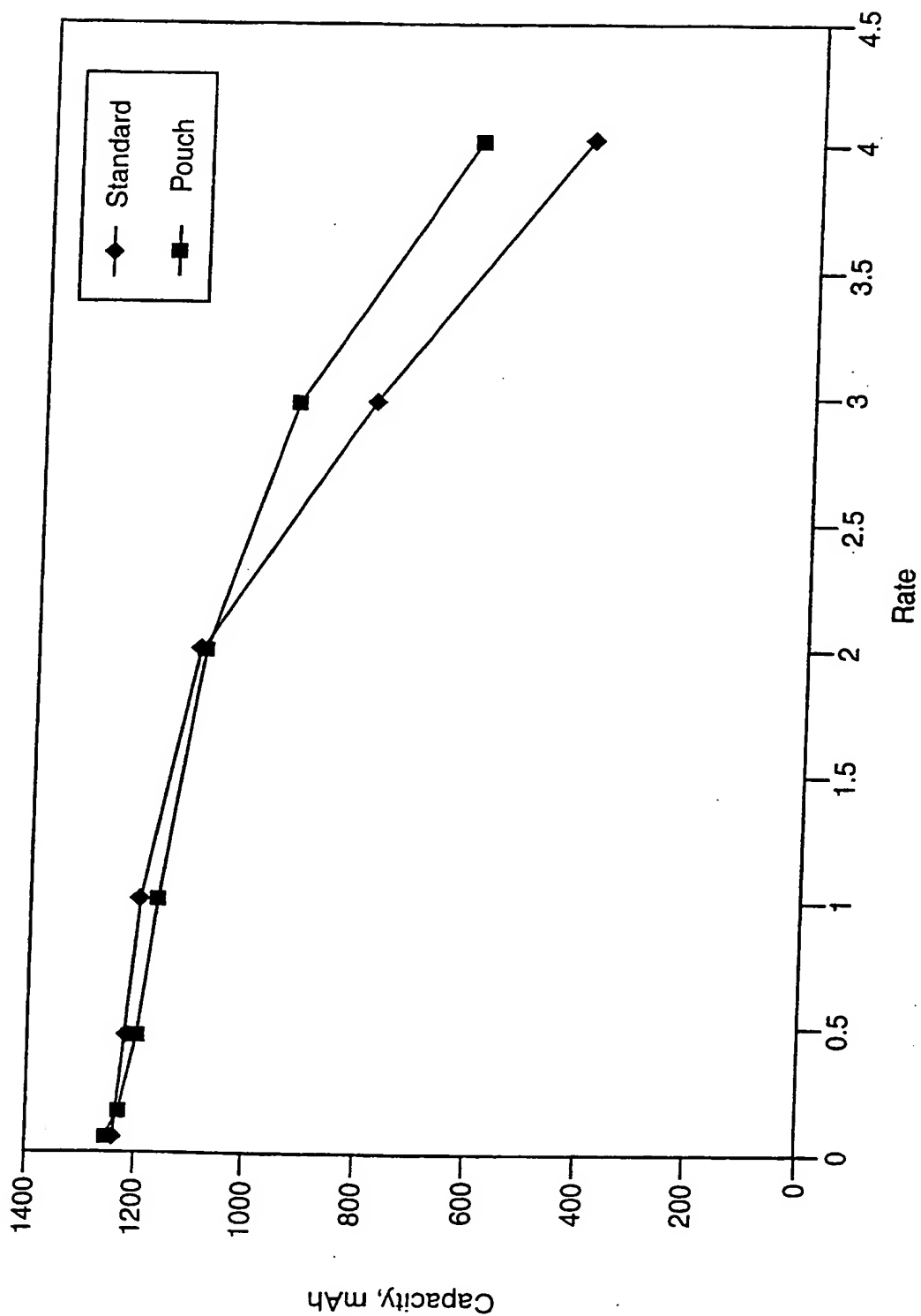


FIG. 6

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US00/12445**A. CLASSIFICATION OF SUBJECT MATTER**

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US CL : Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 29/623.3, 623.1, 623.2; 429/231.95, 247, 324, 326, 131, 133, 136, 145

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
EAST**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,456,000 A (GOZDZ et al) 10 October 1995, col. 3, lines 12-64; col. 4, lines 40-67; col. 5, lines 1-67; col. 6, lines 4-12	1-30
X	US 5,853,916 A (VENUGOPAL et al) 29 December 1998, col. 3, lines 35-61; col. 4, lines 5-67; col. 5, lines 4-61	1-30
X	US 5,470,357 A (SCHMUTZ et al) 28 November 1995, col. 2, lines 1-60; col. 3, lines 23-58	1-30

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Facsimile No. (703) 305-3230

Authorized officer

Angela J Martin

Telephone No. (703) 308-0661

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(71) Applicant (*for all designated States except US*):  
**POLYSTOR CORPORATION** [US/US]; 230 S. Vasco  
Road, Livermore, CA 94550 (US).

(72) Inventor; and

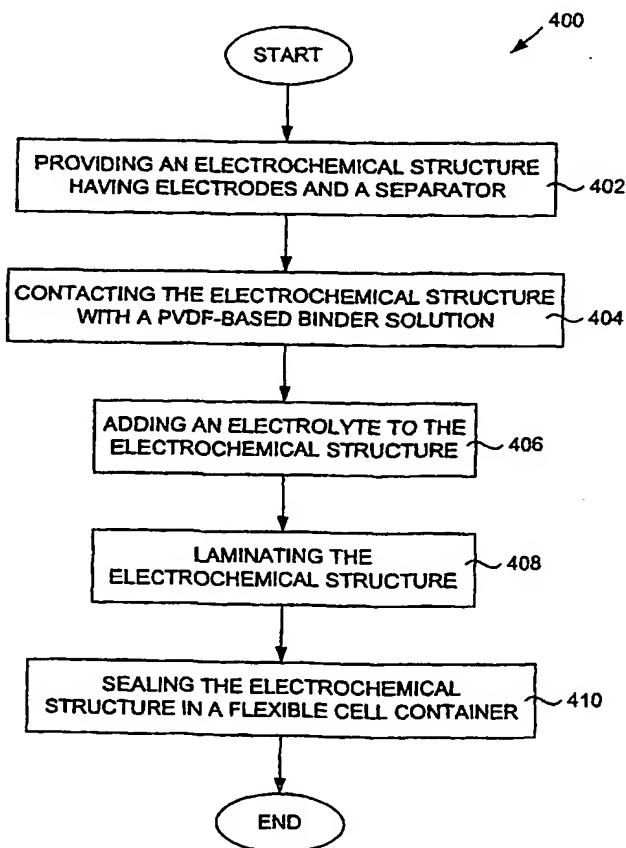
(75) Inventor/Applicant (*for US only*): **COUSTIER, Fabrice**  
[FR/US]; 6561L Cottonwood Circle, Dublin, CA 94568  
(US).

(74) Agent: **VILLENEUVE, Joseph, M.**; Beyer Weaver &  
Thomas, LLP, P.O. Box 130, Mountain View, CA 94042-  
0130 (US).

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[Continued on next page]

(54) Title: METHOD OF FABRICATING A LAMITATED BATTERY CELL



(57) Abstract: Provided are alternative fabrication methods for a lithium-ion secondary battery cell (300). Briefly, the present invention provides processes wherein a binder (105) is applied to a battery separator (104) after winding or stacking the electrodes (106, 108). This is accomplished by soaking previously wound or stacked electrochemical structures, including positive (106) and negative (108) electrodes and a porous separator (104), in a solution containing a binder (105).

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